New prospects for optical lattice clocks on ultracold neutral atoms

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Extremely narrow atomic line corresponding to a strictly forbidden $^1S_0 - {}^3P_0$ transition between ground and metastable states of alkaline-earth-like atoms, currently considered as worthwhile candidates for an optical frequency standard, may be observed either on odd isotopes [1,2] or on even isotopes in external magnetic field [3].

In this paper, we systematically evaluate various sources of uncertainty for the alkaline-earth-like-based optical lattice clock and argue that an accuracy of better 10^{-18} is attainable, which is competitive with that of the best ion clock with Al^+ [4].

In the first part of the paper we propose an accurate optical lattice clocks based on Hg atoms and evaluate the uncertainty of this optical lattice clock by carrying out higher-order calculations of the relevant atomic properties (ac polarizabilities and hyperpolarizabilities, two-photon ionization rate, black-body radiation shift, etc). As a result, we have shown that Hg atom is a promising candidate for highly accurate optical lattice clocks with an estimated uncertainty of less than 10^{-18}, which is mainly limited by hyperpolarizability effects, higher-order multipolar polarizabilities, and black-body radiation effects [5]. On the other side, because of its high nuclear charge, Hg atom may allow a sensitive search of the temporal variation on fine structure constant combined with other optical clocks.

In the second part of the paper we investigate an influence of the localization effects on the light shifts of the clock transition frequency, taking into account the magneto-dipole and quadrupole contributions. In particular, it is shown that in the Lamb-Dicke regime the dependence of this shift on the lattice laser intensity I has the following form

$$\Delta\omega_{clock} = \alpha(\omega)I + \beta(\omega)\sqrt{I} + \gamma(\omega)I^2, \qquad (1)$$

where ω is the frequency of the lattice field. At the magic frequency ω_m the coefficient $\alpha(\omega)$ is exactly zero, while the coefficient $\beta(\omega_m) \neq 0$. Therefore, due to this reason, depending equation (1) on the value $\beta(\omega)$ can have a principal significance for frequency standards from metrological point of view. In the present paper the coefficients $\alpha(\omega), \beta(\omega)$ and $\gamma(\omega)$ are analyzed for some alkaline-earth-like atoms, which may considered as the candidates for the optical frequency standard.

References

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